Importance of extreme events

Robert M. Hirsch
U.S. Geological Survey
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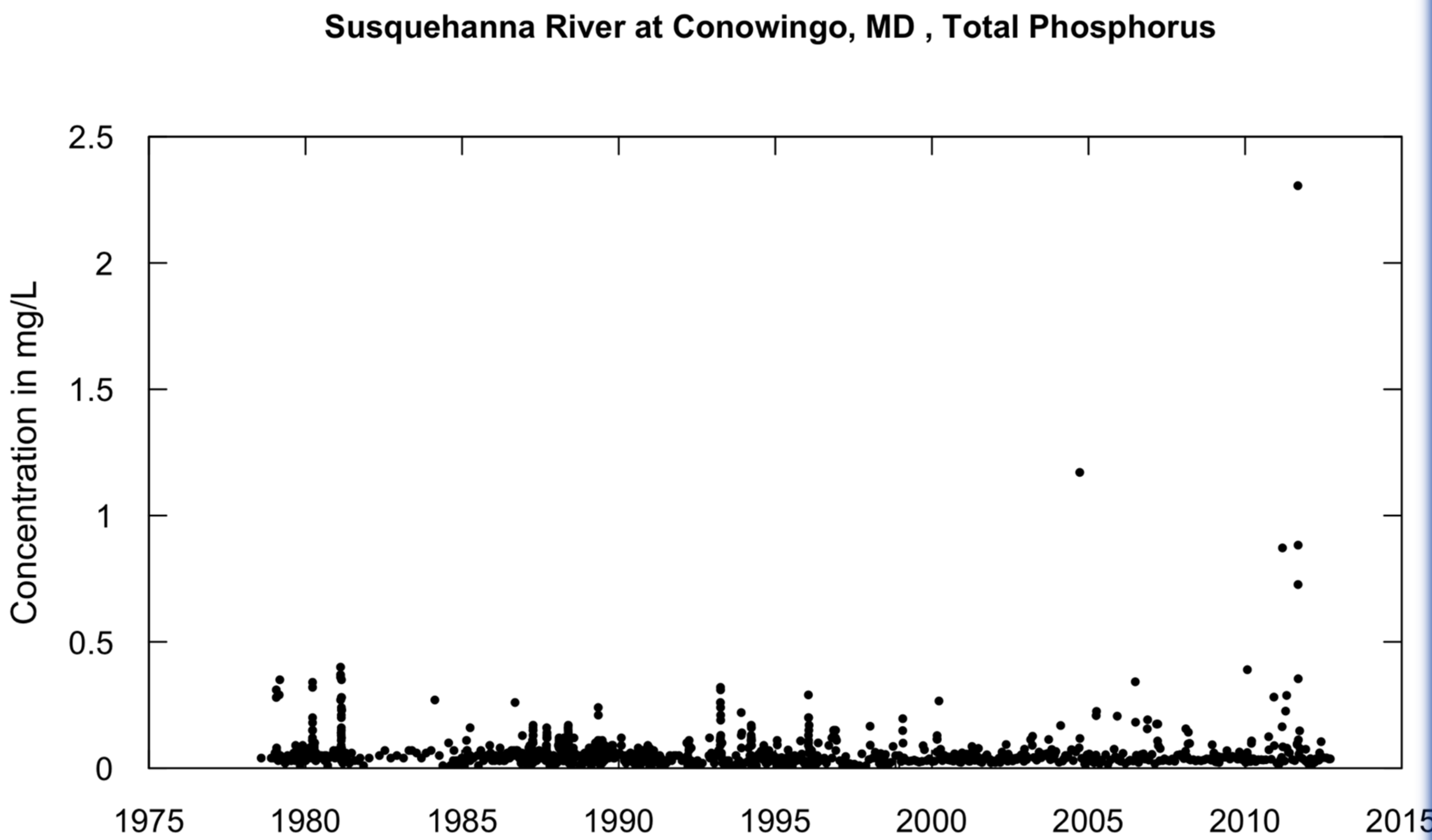
My main points

- Extreme events are natural experiments.
- Samples during floods are critical to estimating fluxes. Continuous monitoring can help.
- Trends in average concentration and trends in average flux can tell very different stories.
- Low or high flow conditions have a lasting impact on water quality.
- Be very skeptical of assertions that we know what enhanced greenhouse forcing will do to hydrologic extremes.

Susquehanna, 70,000 km^2 watershed

Sediment plume from Susquehanna watershed
Plume extends over 150 km down the Chesapeake Bay
Carrying:
Sediment,
Phosphorus,
Nitrogen

From the watershed and from storage in Conowingo Reservoir



Susquehanna River at Conowingo, MD , Total Phosphorus
Concentration in mg/L
2.5
2
1.5
1
0.5
0
1975
1980
1985
1990
1995
2000
2005
2010
2015

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What is happening here?

Did we not observe concentrations at very high discharges before the last few years?

Or, has the behavior of the system at high discharges changed over time?

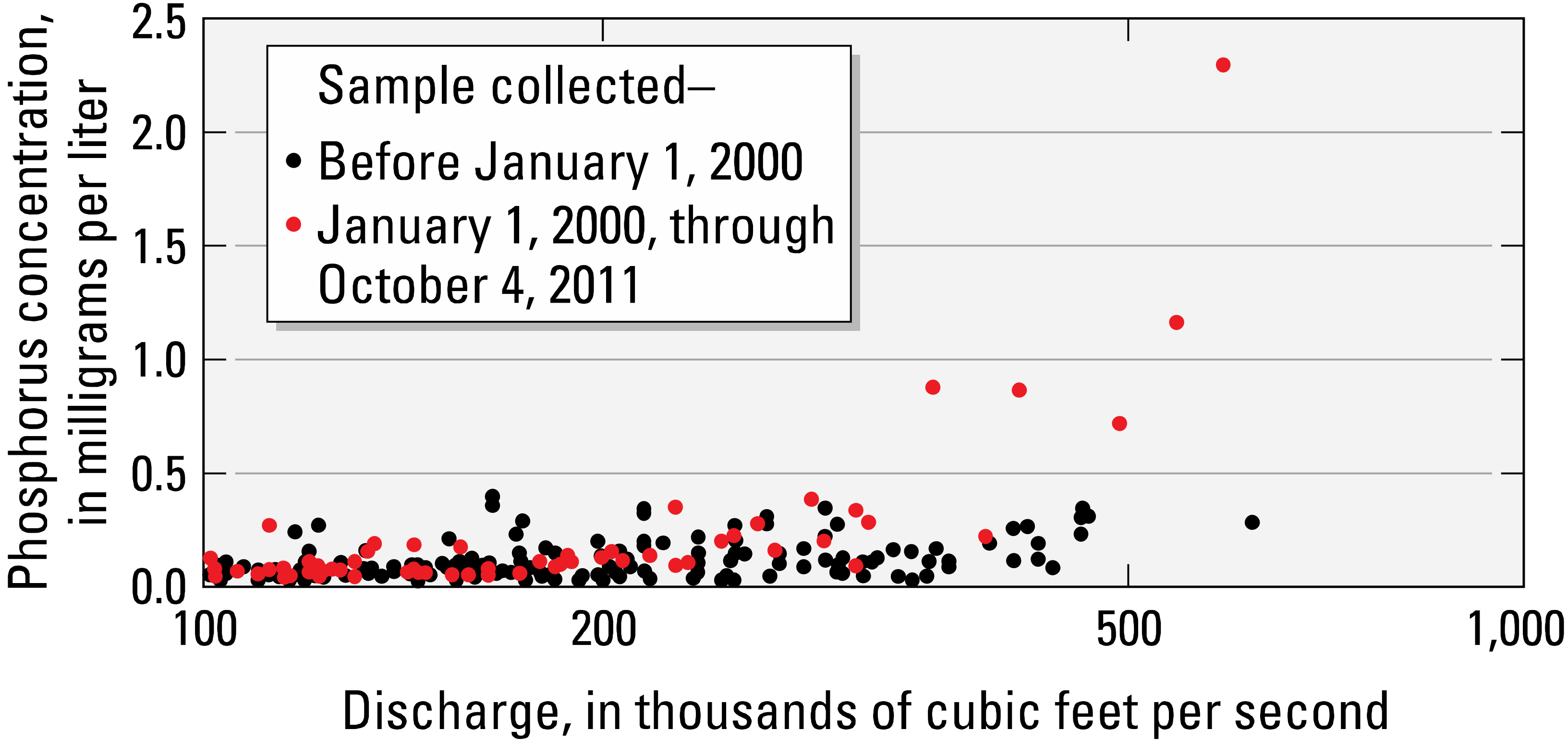

Figure 11. Observed concentration of total phosphorus as a function of discharge for the Susquehanna River at Conowingo, Maryland.

We can model it using WRTDS: Weighted Regressions on Time, Discharge & Season.

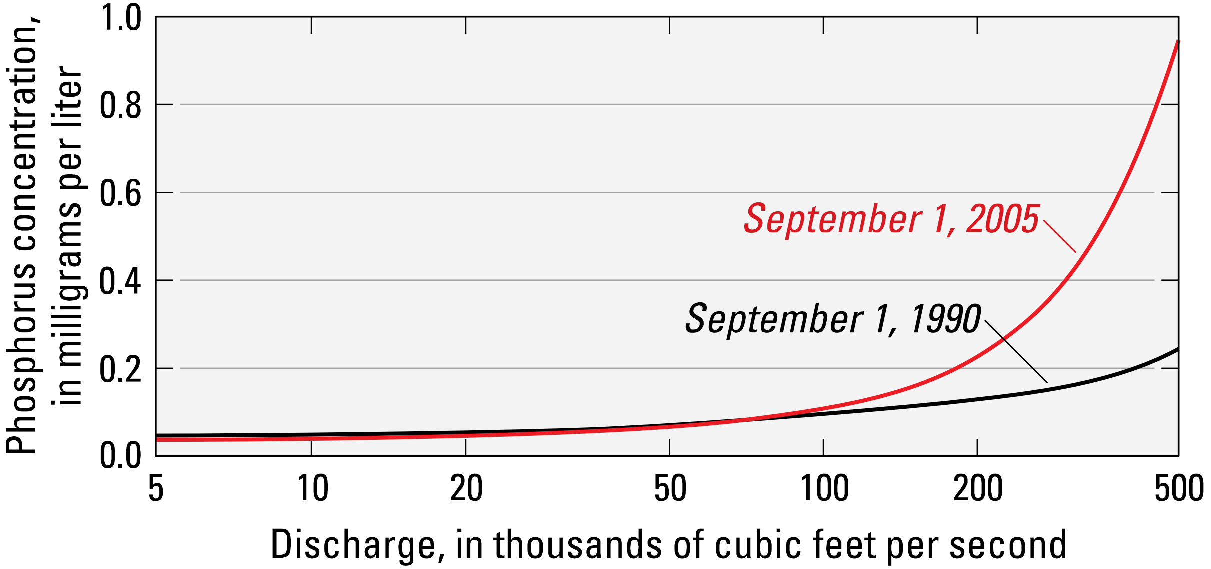

Figure 12. Estimated concentration of total phosphorus as a function of discharge for the Susquehanna River at Conowingo, Maryland, based on smoothing centered on September 1, 1990, or on September 1, 2005.

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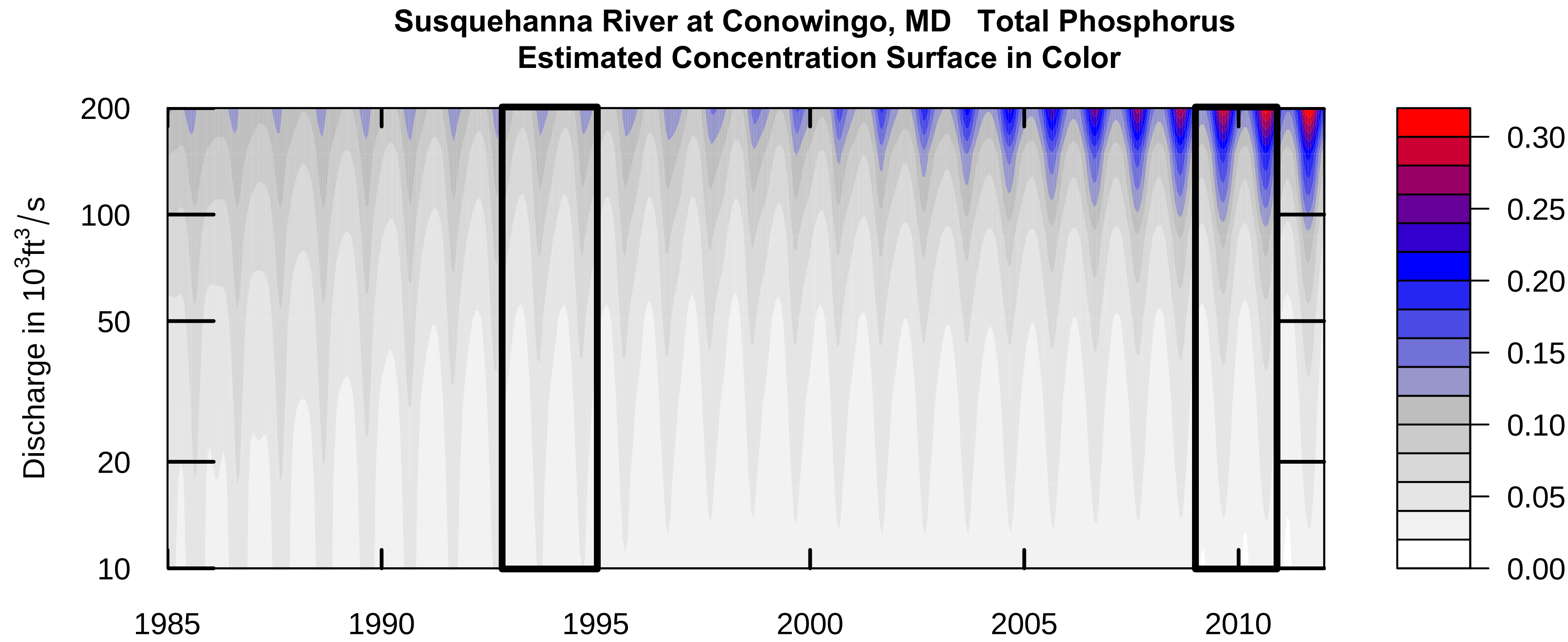
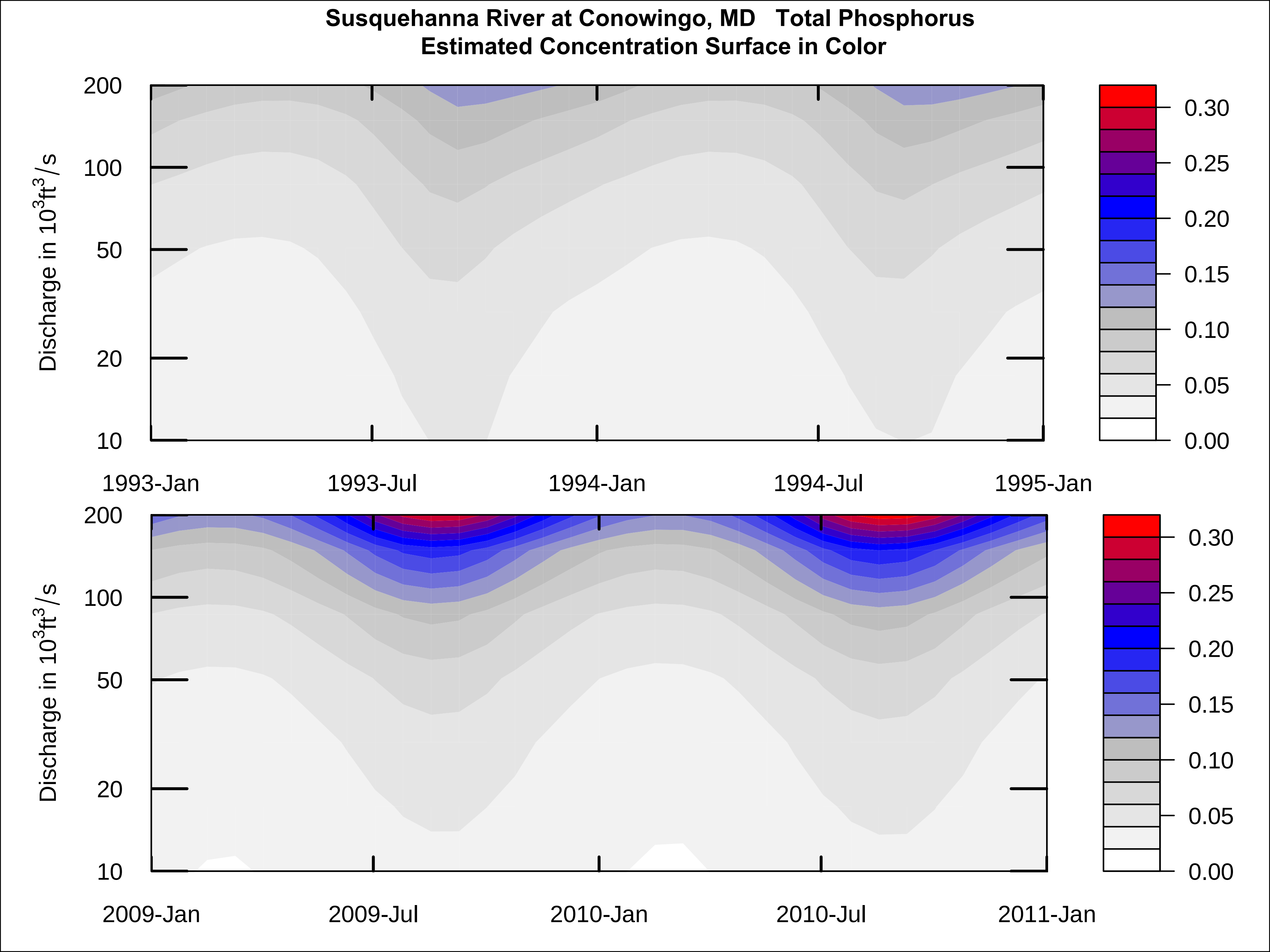
Software now available in R: EGRET package, see https://github.com/USGS-R/EGRET/wiki



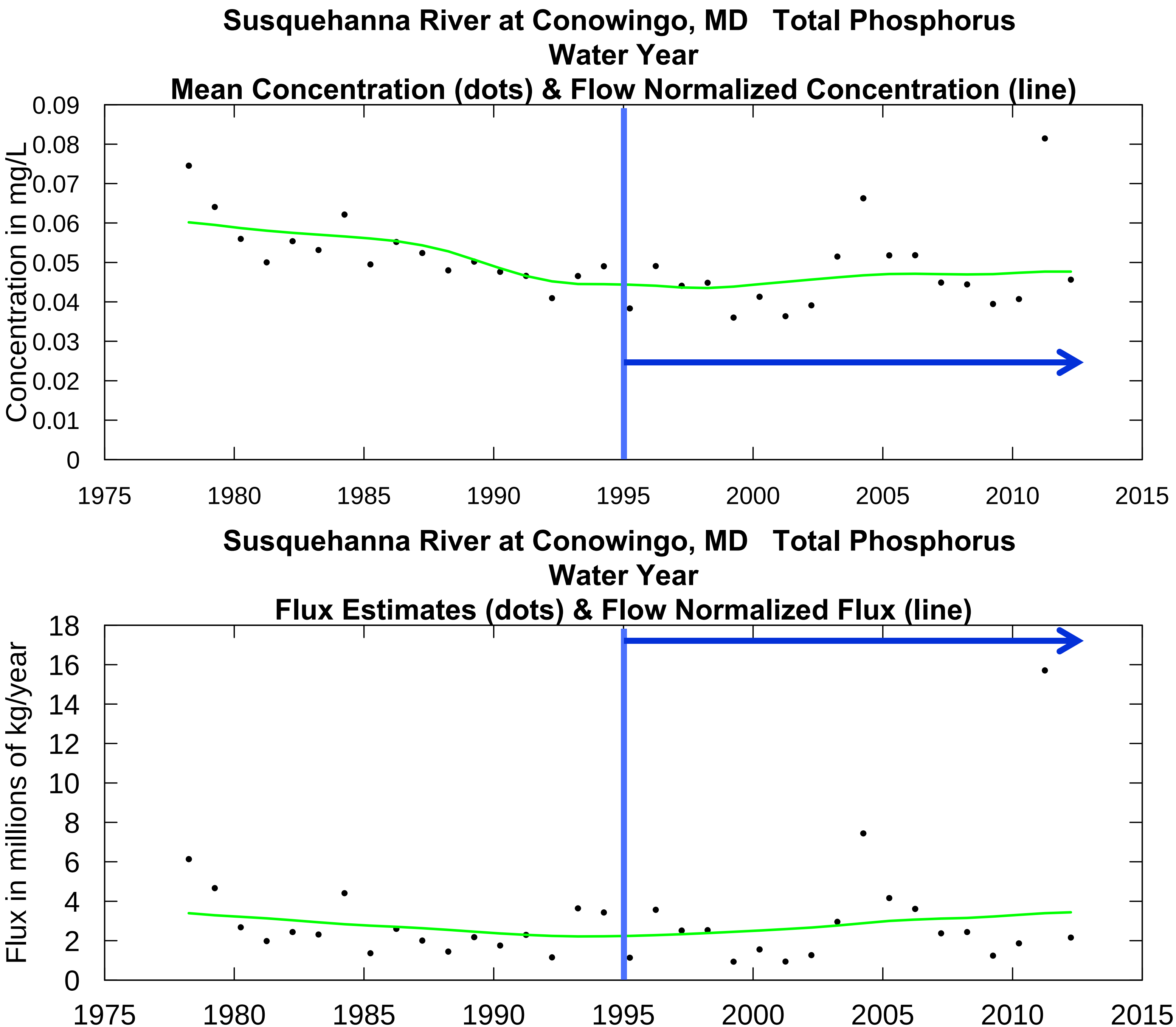
Conowingo Dam during Tropical Storm Lee, September 2011, Reservoir is rapidly filling, Trap efficiency in decline


Susquehanna River at Conowingo, MD Total Phosphorus
Estimated Concentration Surface in Color
Discharge in $10^3 ft^3/s$
200
100
50
20
10
1993-Jan
1993-Jul
1994-Jan
1994-Jul
1995-Jan
2009-Jan
2009-Jul
2010-Jan
2010-Jul
2011-Jan
0.30
0.25
0.20
0.15
0.10
0.05
0.00

Change from 1995-2012

0.4%/yr

3.1%/yr



My Hypothesis:

- As the reservoirs fill: for any given discharge, there is less cross-sectional area, resulting in greater velocity.
- Result: a decrease in the scour threshold (more frequent scour) and greater amount of scour for a given discharge.
- Also a decrease in the amount of deposition at moderately high discharge.
- For most of the last 80 years, output has been less than input. Ultimately, average output must equal average input.
- Unless there is a dramatic decrease in the inputs, the outputs of particulate N and P, and of SS must rise: Either naturally or by engineered removal.

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High flows right after drought

- Example: Iowa River at Wapello, IA
- Published in: Murphy, Hirsch, and Sprague, HESS, 2014, “Antecedent flow conditions and nitrate concentrations in the Mississippi River basin”

High flows right after drought

- We define “flow anomaly” as the ratio of discharge over the past 365 days to long-term average discharge.
- Thus, right after a major drought the flow anomaly would be <1.
- Nitrate anomaly is nitrate concentration residual from the WRTDS model in natural log units.
- There is a significant negative relationship between flow anomaly and nitrate anomaly

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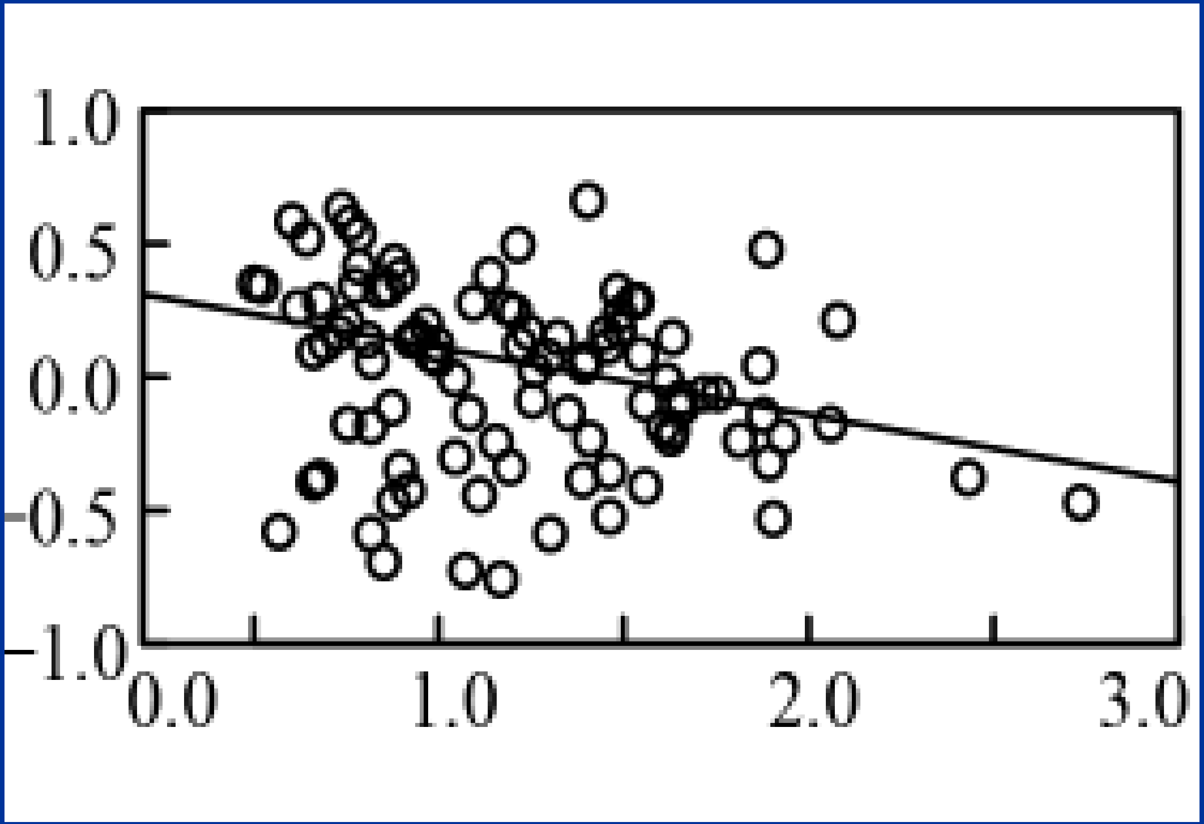
Iowa River at Wapello, IA

Nitrate anomaly



270%

100%

37%

as % of median estimate

Flow anomaly

(flow over last 365 days)/(long-term mean flow)

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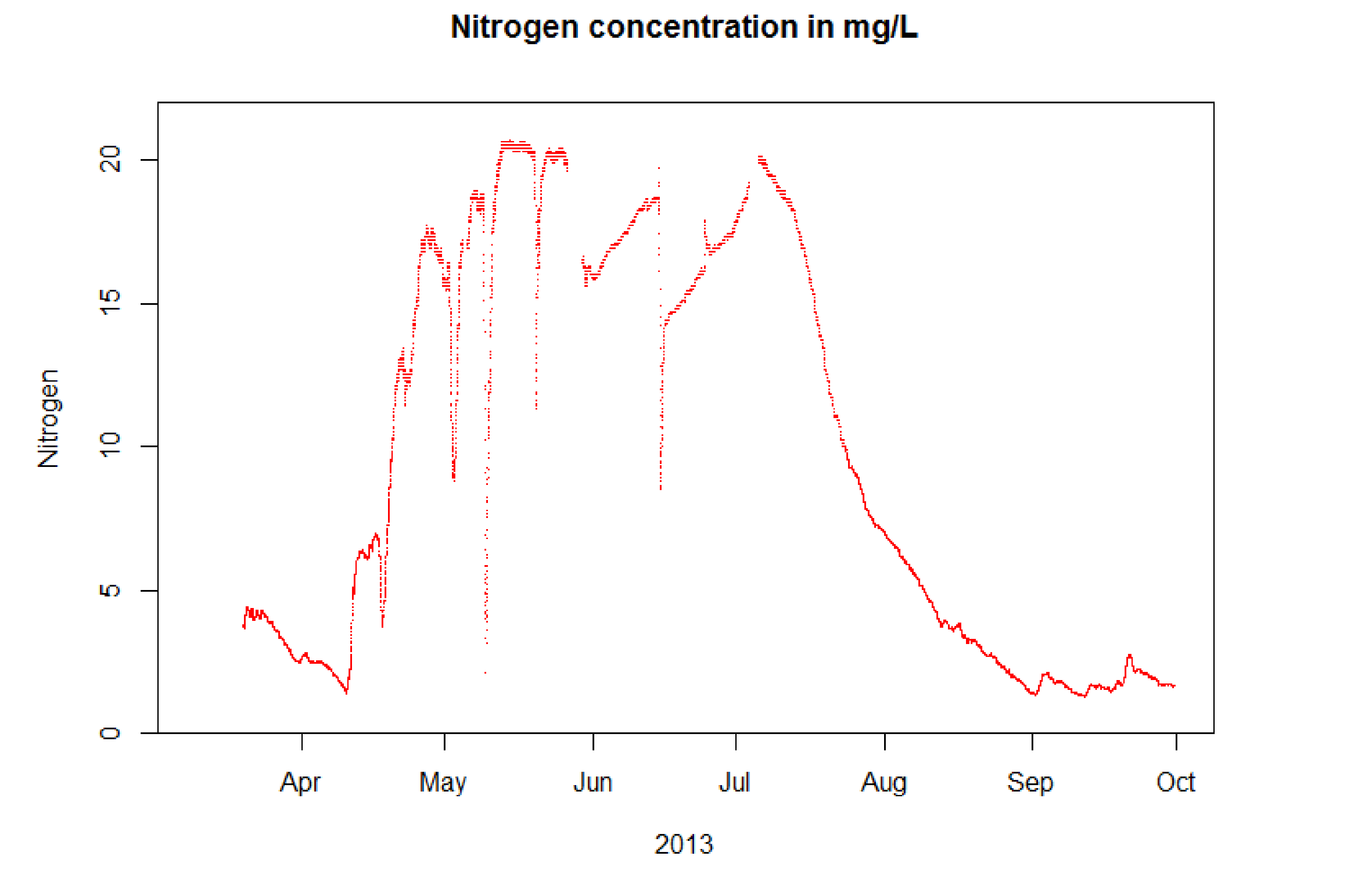
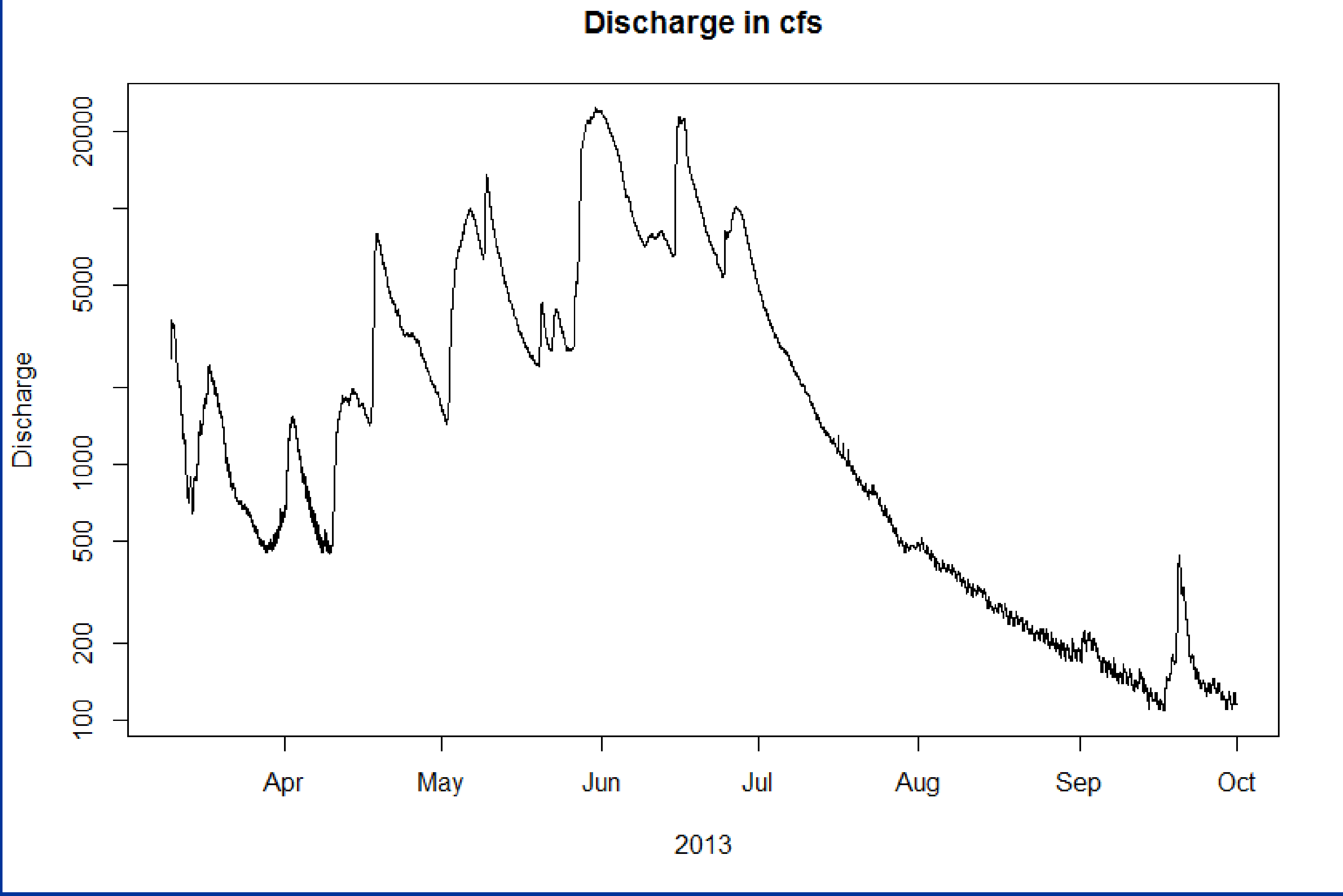
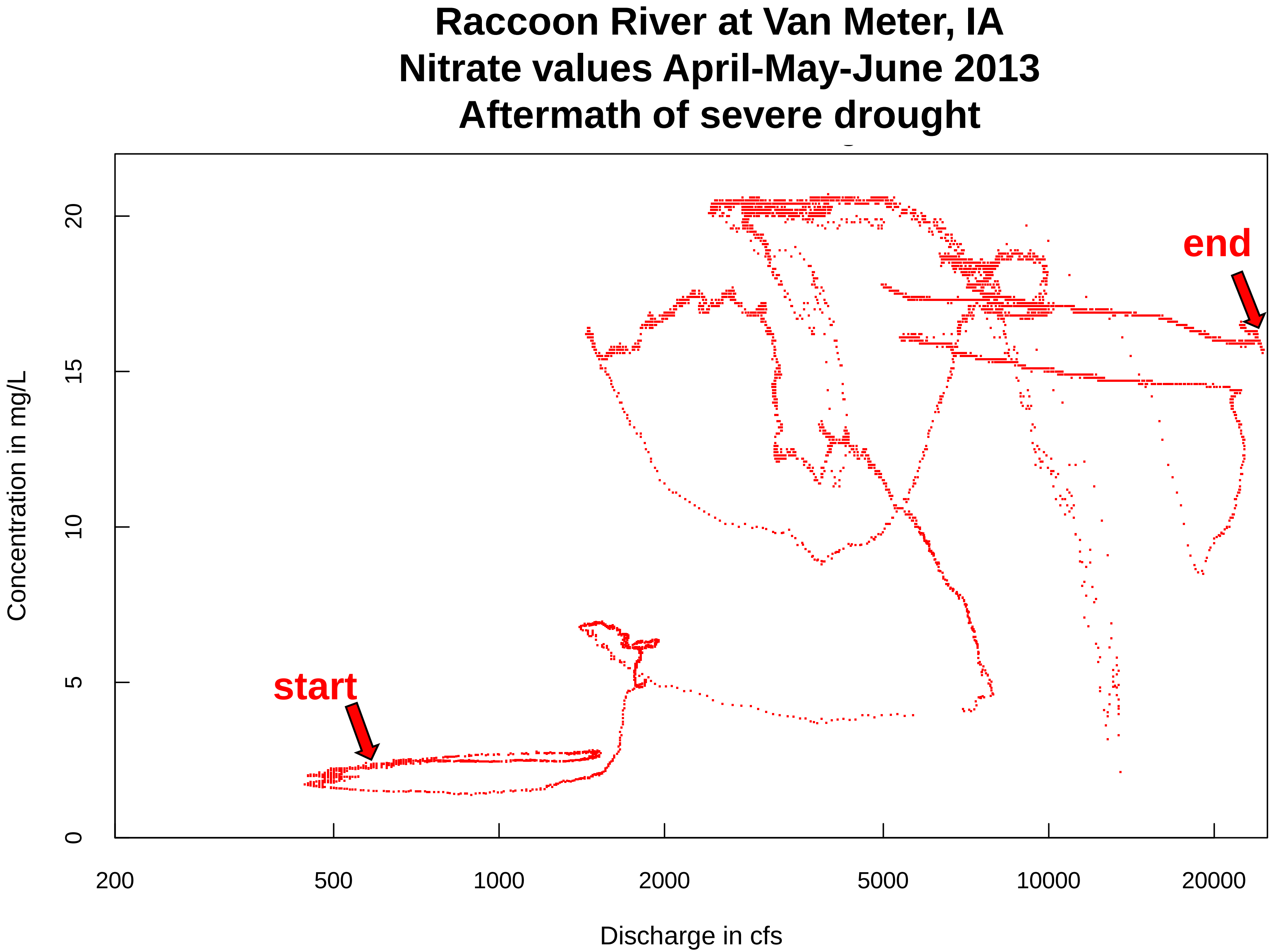
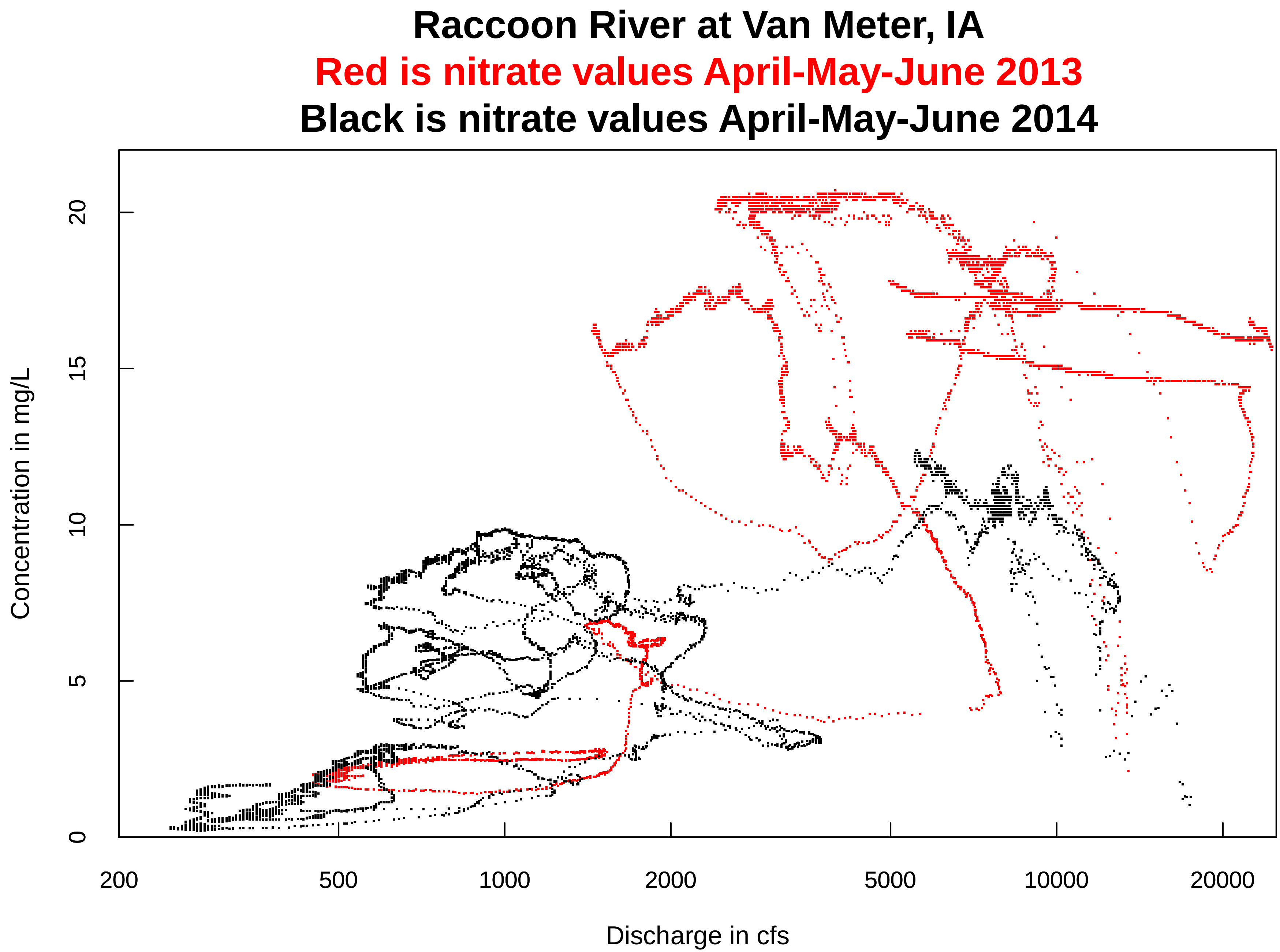
Raccoon River at Van Meter, IA
Nitrate values April-September 2013
Aftermath of severe drought



Raccoon River at Van Meter, IA Discharge April-September 2013 Aftermath of severe drought




Raccoon River at Van Meter, IA
Nitrate values April-May-June 2013
Aftermath of severe drought
Concentration in mg/L
0
5
10
15
20
200
500
1000
2000
5000
10000
20000
Discharge in cfs
start
end



Raccoon River at Van Meter, IA
Red is nitrate values April-May-June 2013
Black is nitrate values April-May-June 2014
Concentration in mg/L
0
5
10
15
20
200
500
1000
2000
5000
10000
20000
Discharge in cfs

Take away messages

- Concentrations in the aftermath of a drought can be very high. A simple concentration versus discharge relationship will not capture this.
- Unusual conditions right after a flood or drought may not be indicative of long-term trends.
- Understanding the processes is far more complex than anything we can learn from monthly or even weekly data.
- But, sparse data is often all we have, and we need to look for changes over all seasons and flow conditions and through multiple floods and droughts.

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Thoughts about climate change and high flows

- **High flows are serially correlated**
- **They tend to "cluster" in time, demonstrating trends can be very tricky**
- **The theoretical and empirical underpinnings of streamflow changes due to greenhouse forcing is very weak.**
- ***Blaming water quality issues on climate change is a "cop-out"***

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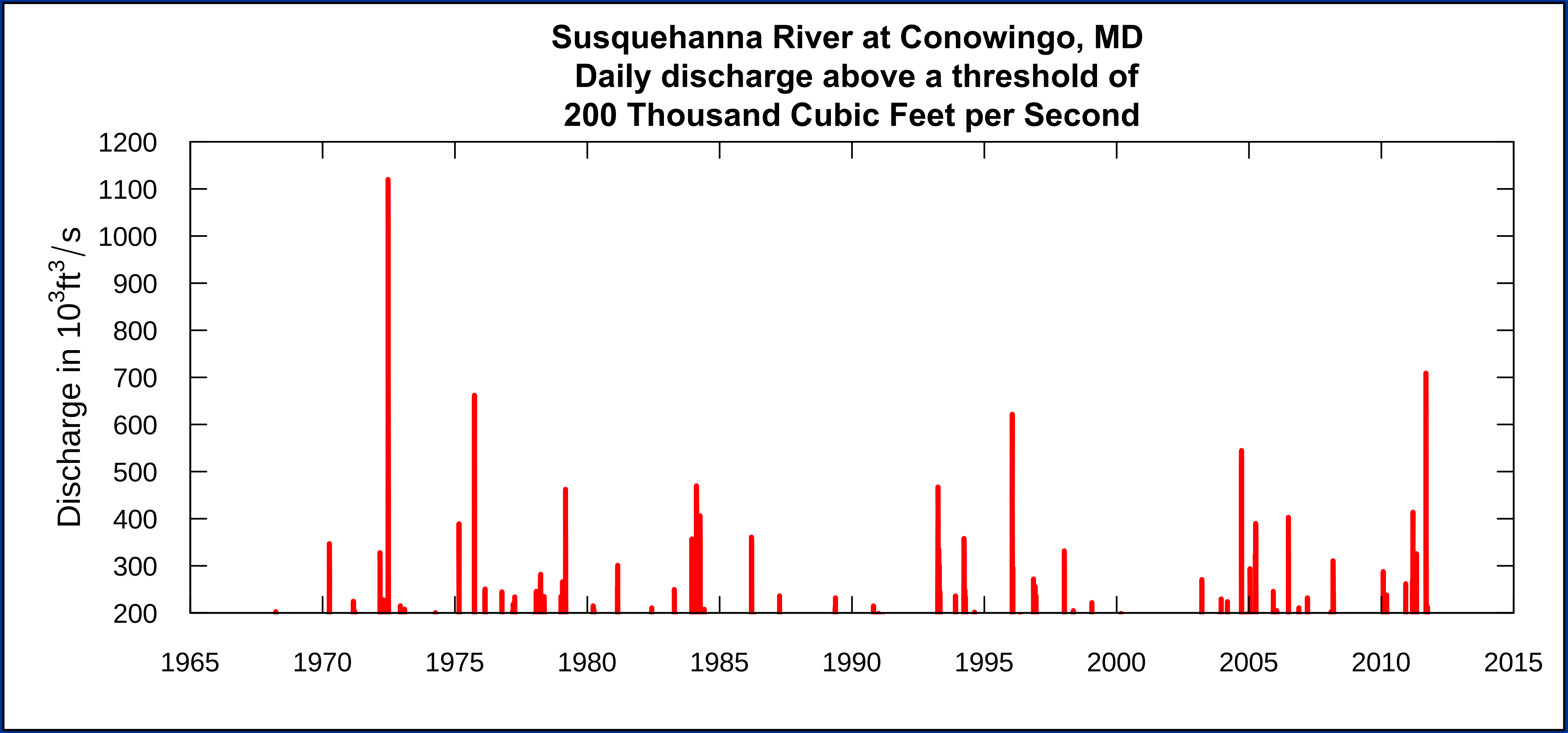
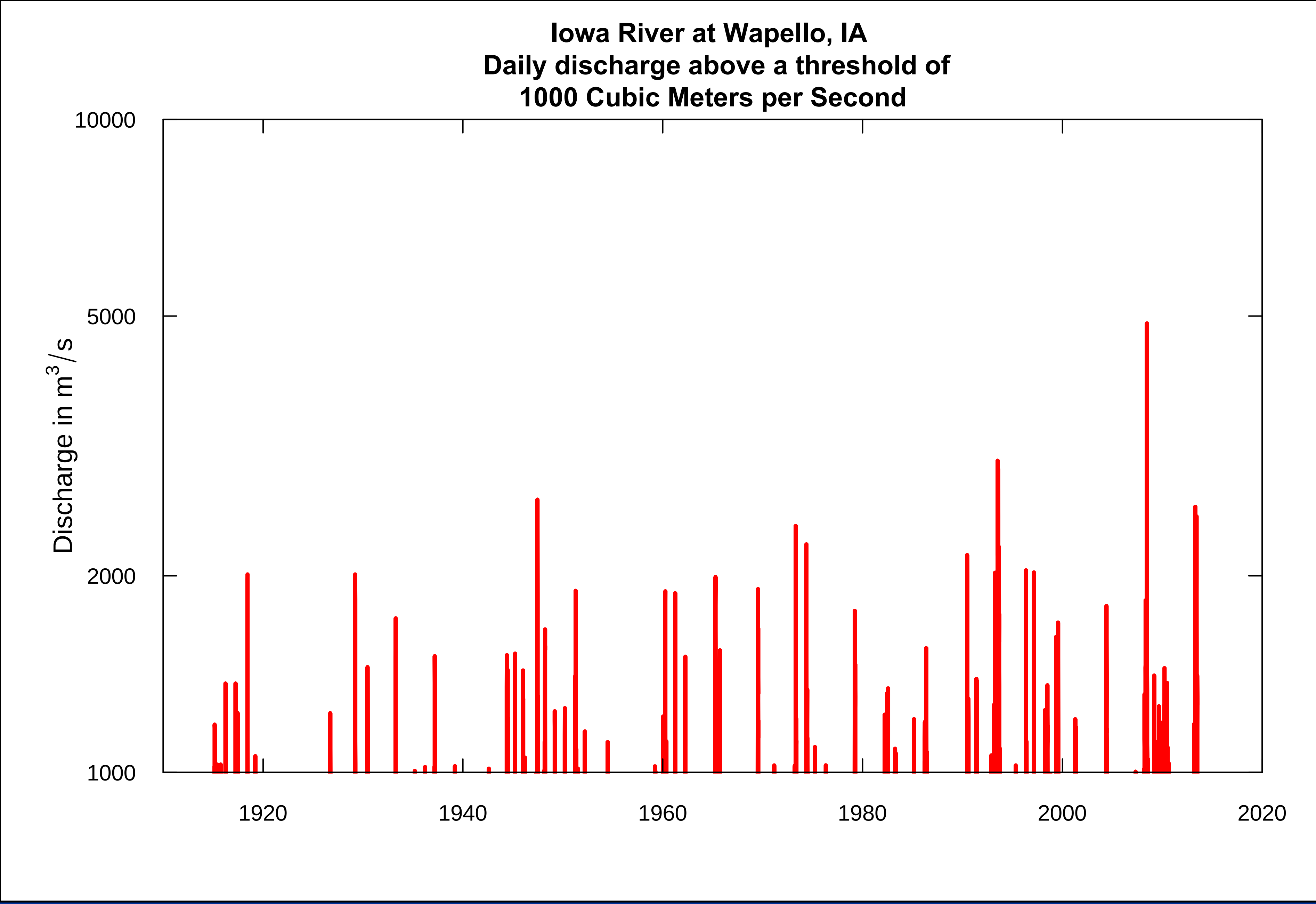
The fact is, floods tend to cluster. It is very hard make a case for a real trend in floods




Iowa River at Wapello, IA
Daily discharge above a threshold of
1000 Cubic Meters per Second
Discharge in m3/s
10000
5000
2000
1000
1920
1940
1960
1980
2000
2020

My main points

- Samples during floods are critical to estimating fluxes. Continuous monitoring can help.
- Trends in average concentration and trends in average flux can tell very different stories.
- Low or high flow conditions have a lasting impact on water quality.
- Greenhouse forcing’s impact on extreme flows is very uncertain.
- New tools for data retrieval & data analysis in R: at https://github.com/USGS-R/EGRET/wiki

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